



Goddard Space  
Flight Center  
National Aeronautics and  
Space Administration



## **Fiber Optic Epoxy Outgassing Study for Space Flight Applications**

NASA/GSFC Component Technology  
and Radiation Effects Branch

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## ABSTRACT: Fiber Optic Epoxy Outgassing Study for Space Flight Applications

Presently there are very few epoxies qualified for space flight and even fewer qualified for space flight optical fiber cable assemblies. Currently, Goddard Space Flight Center uses Tra-Con Bipax, Tra-Bond BA-F253 for all fiber optic space flight cable harnesses. During this study two epoxies from AngstromBond were tested for their outgassing characteristics inside and outside of a cable configuration. The two test epoxies used in the experiment were the AngstromBond AB9119 and the AngstromBond 9112 fiber optic epoxies.

To test the fiber optic epoxy in cable configuration, the test epoxies were used in lieu of Tra-Con Tra-bond F253 epoxy in the preparation of the fiber optic cables. The cables were assembled using Goddard Space Flight Center's standard procedure for space flight fiber optic cable. After assembly the cables were tested for their optical performance and inspected for the physical integrity of the fiber endface. Following the performance testing and visual inspection the cables underwent the outgas testing in a CAHN Microbalance. After the testing, the cable were tested again for performance and inspected for damage.

Upon completion of outgas testing in cable configuration it was apparent that two of the cables were damaged. The damage found in the cables made it necessary for the testing outside of cable configuration to be performed. Failure analysis of the damaged cables revealed that the failure was due to the small size of the cables and not the outgassing of the epoxies.

The testing of the fiber optic epoxy when outside of a cable configuration was conducted using the standard procedures for an ASTM-E595 outgassing test. The epoxy samples were cured in separate aluminum dishes and given to material engineers. The engineers cut the sample into the necessary size and shape and conducted the outgas testing. After the completion of the testing, values for Total Mass Loss and Collected Volatile Condensable Materials were received from the material engineers.

When tested in cable configuration the cables prepared with both the AB9119 and 9112 passed the outgas testing with TML values below 1 percent. However, when the epoxies were tested out of configuration the AB9119 epoxy passed and the 9112 failed. Therefore, the conclusion was made that the AB9119 epoxy qualified for space flight use and the 9112 did not.

## Introduction

The issue of epoxy used for a fiber optic cable assembly or termination is very significant to the reliability of the system and even more crucial in a space flight environment. The epoxy is needed to ensure the precise alignment of the fiber core within the connector. If the integrity of the epoxy's bond of the fiber to the connector is damaged, then the performance of the fiber optic cable will be affected. The integrity of the bond can be affected by contaminants within the epoxy, improper mixing of the epoxy, air bubbles present when the epoxy is injected into the connector, and the outgassing of the epoxy in a vacuum environment (for space flight applications).

To prevent the epoxy from becoming contaminated, especially for space flight applications, fiber optic technicians must wear gloves and other protective clothing. They are also required to perform all termination and curing procedures within a clean room. To combat the adverse effects that improper mixing of the epoxy can create, the epoxies are mixed using an automatic timed mixer that runs on compressed air. The mixer runs for a set period of time and ensures the proper mixing of the epoxy. Air bubbles within the epoxy when the epoxy is injected into the connector can also affect the integrity of the epoxy's bond. Technicians are required to keep air bubbles from affecting the fiber performance by spinning the mixed epoxy in a centrifuge and injecting the epoxy upward into a connector so that all the air escapes before the epoxy is injected. There is no way to prevent the outgassing of an epoxy from occurring. In order to prevent the outgassing of the epoxy from affecting the integrity of the bond, the engineers must conduct outgas testing on the epoxy. The purpose is to demonstrate how much of the epoxy is released and whether or not this outgassing is significant enough to cause shifts in the fiber such that the optical performance or the reliability of the terminated system is compromised.

The outgas testing of an epoxy is significant because it is the only validation that the epoxy and the terminated system can withstand a vacuum environment. It is very important to make sure that the integrity of the bond and termination is kept, especially in space flight applications where the fiber optic cables cannot be easily replaced. Also any materials released by the epoxy in a vacuum environment could block the transmission of light through contamination of the optical endface or place a stress on the fiber that could result in breaks and cracks. These events could cause a major failure in those components that are using the fiber for communication and data transmission and potentially result in loss of equipment or loss of life if used on a critical system in a manned space craft. The potential for such a great impact on other systems makes the outgas testing of the epoxy such an essential test.

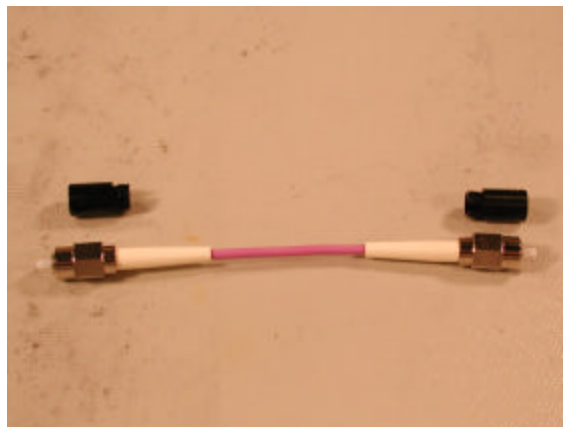
## Background

Most of the outgas testing is conducted by materials engineers for Goddard Space Flight Center using a system that is a "diffusion pumped facility" with "a glass cylindrical bell jar containing the outgassing test apparatus specified in ASTM E595-93." (Illustration 1)

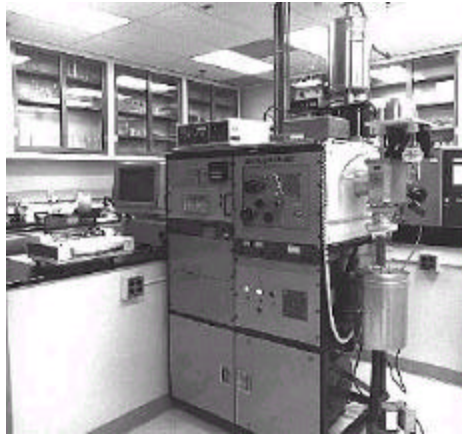


**Illustration 1**

This testing system is known as an "ASTM E595" test. However, this system does not accurately depict the behavior of the amount of epoxy used in the manufacturing of a fiber optic cable. The ASTM E595 test uses 100 to 300 milligram samples during the testing, but an actual fiber optic cable uses far less than the 100 to 300 milligrams used in the ASTM E595 test. To better simulate the behavior of the epoxy when it outgasses within a fiber optic cable assembly a different testing system was used. Instead of testing with the typical ASTM E595 system, the epoxy was evaluated in the termination of a fiber optic cable assembly and the entire assembly (Illustration 2) was tested using another system known as a CAHN recording vacuum balance (Illustration 3).



**Illustration 2**



**Illustration 3**

The use of the CAHN balance system allowed for the observation of the position of the fiber's core within the connector and the presence of any voids that may have occurred in the ferrule filled with epoxy. The CAHN system, while allowing for the testing of the whole cable assembly, still was used to determine the amount of material that was outgassed by the epoxy or the percent contribution of the epoxy material to the materials collected from the cable assembly in a vacuum environment.

### Experimental procedure

The experimentation completed in this study was completed in three phases: termination of the samples for testing, configuration testing and epoxy testing in a vacuum environment, and data analysis of the results.

The first phase of the experimentation was the assembly and preparation phase. This phase of the experimentation ensured that each cable met set space flight cable requirements and that the cabling and connectors did not interfere with the data collection within the outgas testing. This phase also ensured that the epoxy samples used in the ASTM E595 test would be an accurate representative of any sample of the test epoxies. The fiber optic cables were prepared and terminated using the standard space flight procedures and the epoxy samples were prepared using the procedures set by the manufacturer and modified with space flight required procedures. Before the prepared cables underwent outgas testing they were inspected visually for faults within the connector and ferrule and then tested for adequate levels of insertion loss.

The second phase of the experimentation was the testing phase. In this phase the fiber optic epoxy underwent the outgas testing and the values for the epoxy's outgas characteristics were collected. The epoxy was tested in cable configuration and out of cable configuration. The in cable configuration testing was conducted using the CAHN recording vacuum balance and the out of cable testing was conducted using the ASTM E595 system. The CAHN recording vacuum balance system measures weight loss of specimens versus time while in vacuum. Temperatures

of up to 125°C can be applied to the specimen. Initially, the sample is weighed manually and inserted in the balance, where a vacuum is produced. As the sample loses weight, the weight loss is automatically recorded with digital interface software that runs on a IBM PC Computer. If the weight change exceeds the recording range on the recorder, it will automatically rescale itself. The system will perform this operation until a maximum of 10g is lost from the sample. Weight loss is monitored until equilibrium is reached. The chamber cycled the temperature from 25°C to 75°C over twenty-four hours at a constant rate. The vacuum chamber is 2 inches in diameter by 20 inches long. The sample fiber optic cable assembly was hung vertically within the chamber. The ASTM E595 system used at GSFC is a micro-CVCM apparatus. The apparatus presented in ASTM E 595-77/84/90 has a number of critical dimensions to ensure that similar systems should produce similar results. These critical dimensions are described in E 595-77/84/90. A number of samples can be tested at one time in the vacuum system. Each sample, of 100 to 300 milligrams mass - nominally 250 milligrams - is placed into a pre-weighed aluminum foil boat, which has been thoroughly cleaned and dried. Following a 24-hour pre-conditioning at 25° C, 50% relative humidity and standard atmospheric pressure to ensure that the samples receive a common preliminary treatment, the individual samples are weighed. The samples are then loaded into individual compartments in a solid copper bar that can be heated. Each compartment is closed by a solid copper cover, requiring that all volatile materials escape only through a 6.3-mm (0.25-in.) diameter exit port. The copper heater bar, having 12 sample compartments, is heated to 398 K (125° C) for 24 hours. The sample is also heated to 398 K (125° C) by conduction and radiation. This causes the volatile materials to be driven off, with their only escape being through the exit port. At a distance of 12.7 mm (0.5 in.), a chromium-plated collector is in direct line of sight of the exit port and is maintained at 298 K (25° C). A significant portion of the escaping volatiles collects on the chromium-plated disk if the condensation temperature is 298 K (25° C) or above. Barriers are near the collector plate to prevent cross-contamination between adjacent samples. The mass loss of the sample is determined from the weights before and after the 398 K (125° C) exposure, and the percentage loss is calculated to provide the TML. In a similar manner, the difference between the weight of a clean collector and of the collector having condensed materials will provide the mass of condensables. This mass of condensables is calculated as a percentage of the starting mass of the sample, and stated as CVCM. During the outgas testing with both systems the values for Total Mass Loss (TML) were collected. Additionally, when the epoxy was tested using the ASTM E595 system values for Collected Volatile Condensable Materials (CVCM) were obtained.

The third phase of the experimentation was the analysis phase. In this phase the fiber optic cables were again inspected for faults, voids, or damages caused by the releasing of the materials in the vacuum environment using a high powered microscope. The cables were also tested again for insertion loss values to ensure that there was no damage to the fiber that could not be seen.

The termination procedure for Phase One is documented below.

#### Cable Configuration Test Samples

- Cable Preparation
  1. Cut required length of fiber, 6.3 inches, off of the spool for each cable.
  2. Cut outer jacket to required length, 3.9 inches, for each cable.

3. Use stripper (Claus No-Nik) to remove 0.4 inches of outer jacket from each end of cable to expose strength members.
  4. Cut inner buffer tubing to 0.12 inches away from outer jacket.
  5. Inspect fiber for any nicks or cuts.
- Cable Stripping
    1. Pour stripping formula of Sulfuric Acid (95-98%) into 100mL beaker.
    2. Place beaker on hot plate and heat up to 142°C (+5°C, -2°C).
    3. Fill 3 100mL beakers with Deionized water.
    4. Fill 1 100mL beaker with 2-Propanol alcohol
    5. Place fiber end into acid for 1 minute when reaches 142°C.
    6. Remove carefully and place fiber end in each beaker of Deionized water for 30 seconds.
    7. Place fiber end into 2-Propanol beaker and swish around for 1 minute.
    8. Wipe dry with small kim-wipe.
    9. Repeat as necessary.
  - Cable Cleaning
    1. Wipe all beakers down with clean solvent prior to use.
    2. Wipe all tweezer surfaces with cleaning solvent and place on large, clean dry wipe.
    3. Fill two labeled beakers with cleaning solvent as follows: 100ml to beaker #1 and beaker #2
    4. Place epoxy syringes in beaker #1
    5. Operate ultrasonic cleaner for five minutes and place syringes on clean dry towel.
    6. Place one packet of connector parts into beaker #2.
    7. Operate ultrasonic cleaner for five minutes using beaker #1 and placed syringes on clean dry towel
    8. Repeat for number of desired connectors using beaker #2 (one packet per connector).
  - Epoxy Mixing
    1. Open epoxy packaging and remove middle separation clip.
    2. Squeeze the package to start mixing.
    3. Place the package on pad inside the TraCon automatic timed mixer.
    4. Turn on the automatic mixer and wait 5 minutes.
    5. Place epoxy package in the centrifuge and turn on for 3 minutes  
(making sure that centrifuge is balanced).
    6. Cut package open and poured into pre-cleaned syringe.
    7. Insert syringe piston and pushed piston until all trapped air is expelled.
  - Termination
    1. Clean the entire stripped cable end and allow to dry for five minutes.
    2. Place pre-cleaned connector boot and crimp sleeve on fiber.
    3. Insert syringe into back of the connector body until it butted against the ferrule and squeeze enough in until a small bead appeared at the ferrule tip.

4. Slowly remove the syringe while ensuring that the rear barrel is kept full of epoxy as the tip is withdrawn.
  5. Blot excess epoxy from the ferrule face.
  6. Insert the fiber into the connector using a vertical rotation and push the fiber gently down until the fiber emerged from the ferrule and can not be inserted farther.
  7. Put a thin coat of epoxy in the outside threads of the rear connector body.
  8. Slide the crimp sleeve up against the connector body and crimp the sleeve around the rear barrel of the connector.
  9. Place the connector into the curing oven for 35 minutes at 120° C.
  10. Once cured, scribe the fiber with the scribe using a gentle motion.
  11. Gently grasp the fiber and pull the excess away from the ferrule face.
  12. Repeat for 2<sup>nd</sup> connector for each cable needed.
- Polishing
    1. Use the Buehler Fibermet Polisher to polish the connector end face in the following sequence:
      - a. Use wet 3 micron diamond film polish for 10 arm cycles or 50 seconds and clean end with alcohol.
      - b. Use wet 1 micron diamond film polish for 10 arm cycles or 50 seconds and clean end with alcohol.
      - c. Use dry 0.5 micron diamond film polish for 10 arm cycles or 50 seconds and clean end with alcohol.
      - d. Use dry 0.1 micron diamond film polish for 5 arm cycles or 25 seconds and clean end with alcohol.
      - e. Use 0.05 micron aluminum oxide film polish for ½ wet and ½ dry arm cycles or 5 seconds.
      - f. After completing polishing sequence clean the fiber end with alcohol.
  - Inspection
    1. Using the Buehler Fiberscope inspect the fiber end at a magnification of 200x.
    2. Ensure that the connector face is free from cracks, scratches, edge chips, hackles, pits and other anomalies.
    3. If any anomalies are present re-polished the endface using a half time procedure starting with the 0.5 micron diamond film.
    4. If no anomalies are present cover endface with a dust cap and place aside for testing.
    5. After polishing is complete, use multimeter, power sensor, and laser source to conduct insertion loss testing and record data for each cable.

#### Out of Configuration Test Samples

- Epoxy Sample Preparation
  1. Open epoxy packaging for AB9119 and remove middle separation clip.
  2. Squeeze the package to start mixing.
  3. Place the package on pad inside the TraCon automatic timed mixer.
  4. Turn on the automatic mixer and wait 5 minutes.
  5. Place epoxy package in the centrifuge and turn on for 3 minutes



- (making sure that centrifuge is balanced).
6. Cut open epoxy package and pour approximately half of 2.5 package into precleaned aluminum foil boat.
  7. Place aluminum boat on curing oven and cure for 30 minutes at 120°C
  8. Repeat steps for other epoxy sample, 9112, and cured at 90°C for 30 minutes.

The procedures used for Phase Two are documented below:

- CAHN Recording Vacuum Balance system
  1. Place one terminated cable into testing cylinder of MOLIDEP CAHN Vacuum Balance
  2. Start the outgas program of the MOLIDEP as specified in NASA Directive No. 541-WI-5330.1.14
  3. After completion of the testing compile the data and analyze.
  4. Compare results to specification values of space flight materials.
  5. Repeat for each additional cable.
- ASTM E595 system
  1. Place epoxy sample within E-595 testing apparatus.
  2. Begin procedures specified in ASTM E-595-90.
  3. Remove sample and compile data.
  4. Compare results to specification values of space flight materials.
  5. Repeat for second epoxy sample.

The procedures for Phase Three were:

1. Re-inspect fiber ends using Buehler Fiberscope and check for any changes in the fiber's position or condition.
2. Use multimeter, power sensor, and laser source to conduct insertion loss testing and record data.
3. Use OTDR to determine if the cable has experienced any damages due to the outgassing of the epoxy

## Instrumentation

Each phase of the experimentation required specific equipment.

Equipment used during Phase One:

- Curing Oven, OFCI # 08-0028-OFC, 24 port for ST/FC/SMA/SC
- Clauss No-Nik, NN023
- Ideal Jacket Stripper, 45-164
- 3M Diamond angled Scribe, 05-00010
- Clauss Scissors, 925C
- Tec Cut Strength Member Shears, 702SC023
- Clauss Fiber Trash Can, FS200

- Molex Syringe & Tip, 86710-0023
- Lint Free Kim Wipes
- Alcohol Reservoir Bottle
- 95-98% Sulfuric Acid
- Buehler Fibermet Optical Fiber Polisher, B-0273
- 3, 1, 0.5, 0.1, and 0.05 micron polishing paper
- Tracon Roller & pad, MXR-1001

Equipment used during Phase Two:

- NASA/GSFC MOLIDEP CAHN Vacuum Balance
- E-595 Outgas testing apparatus outlined in ASTM E-595-90

Equipment used during Phase One & Three:

- Noyes Testing Kit, with 850 nm Power Meter, 850 nm Light Source, MLP4-2
- Buehler Fiber Termination Inspection Fiberscope Zoom 200-400X, Buehler #0801-0504
- Nikon SMZ High Powered Microscope
- Nikon Digital Camera
- HP 8153A Lightwave Multimeter
- HP 81532A Power Source
- HP 81551MM Laser Source
- OPTO Electronics Inc. Optical Fiber Monitor, Model OFM130

## Data and Results

All the samples underwent outgas testing in a vacuum environment for Total Mass Loss (TML) and/or Collected Volatile Condensable Materials (CVCM). The values for TML and CVCM were then analyzed and specific characteristics of each of the epoxies were revealed. Before the outgas testing, the fibers underwent visual inspections (Table 1) for detection of shifts or unwanted movement of the fiber's core and optical testing (Table 2) to monitor the performance values of the test cables. After completing the outgas testing, the fibers again underwent visual inspections (Table 1) to detect shifts or unwanted movement of the fiber's core and optical testing (Table 2) to monitor the optical performance values of the test cables.

The original hypothesis of the experimentation was that all the epoxies would qualify for use in space flight components. Each of the epoxy would share the standard characteristics that other space flight qualified epoxies have, such as cure time, cure temperature, Total Mass Loss, and Collected Volatile Condensable Materials. The values for Total Mass Loss (Table 3 & 4) and Collected Volatile Condensable Materials (Table 5) for each of the epoxies would be under 0.1 percent. The epoxies would experience no shifts in shape and no reduction in performance values after testing in the vacuum environment.

The testing was conducted using a CAHN Microbalance, an E-595 outgas testing apparatus, optical sources and receivers, an optical fiber monitor, and high-powered microscopes. The microbalance and outgas testing apparatus held the sample fiber optic cable in a vacuum environment and recorded the mass of the material that was released by the epoxy and cable. The mass of the material released was compared to the total mass of the cable before and after the testing. The comparison resulted in values for Total Mass Loss and Collected Volatile

Condensable Materials for each of the epoxies. These values were compared to the standards for outgas testing, TML of less than one percent and CVCM of less than 0.01 percent. It was determined whether or not the epoxies met these standards and then conclusions were drawn.

The results from the testing from the ASTM E595 testing can be seen in Tables 7&8.

<b>Visual Inspection</b>		
Cable	Before	After
9112 Cable # 1 End A	PASS	FAIL (no back light present)
9112 Cable # 1 End B	PASS	PASS
9112 Cable # 2 End A	PASS	PASS
9112 Cable # 2 End B	PASS	PASS
AB9119 Cable # 1 End A	PASS	PASS
AB9119 Cable # 1 End B	PASS	PASS
AB9119 Cable # 2 End A	PASS	PASS
AB9119 Cable # 2 End B	PASS	FAIL (no back light present)

**Table 1**

<b>Insertion Loss For Fiber Optic Cables (in dB)</b>		
Cable	Before Testing	After Testing
9112 Cable # 1	0.02 dB	No Light
9112 Cable # 2	0.01 dB	0.18 dB
AB9119 Cable # 1	0.01 dB	0.01 dB
AB9119 Cable # 2	0.01 dB	No Light

**Table 2**

Total Mass Loss While in Cable Configuration (in percentage of total mass)	
9112 Cable # 1	0.06545 %
9112 Cable # 2	0.03106 %
AB9119 Cable # 1	0.01934 %
AB9119 Cable # 2	0.03045 %

**Table 3**

Average Total Mass Loss of Epoxy Alone (in percentage of total mass)	
Epoxy (9112)	4.33%
Epoxy (AB9119)	0.64%

**Table 4**

Average Collected Volatile Condensable Materials of Epoxy (in Grams, when tested alone)	
Epoxy (9112)	1.34%
Epoxy (AB9119)	0.00%

**Table 5**

# MICRO VCM TEST REQUEST AND DATA SHEET PER ASTM E-595-93

(Requestor please read, then furnish all information above asterisks.)

Requested by: **Matt Bettencourt**

Phone: **6-8311**

Date: **4/12/01**

Material Identification (product name, number, description, classification, etc.)

**Angstrom Bond 9119 Fiber Optic Epoxy**

Manufacturer of Material (Name, City and State Address): **Fiber Optic, Inc., 23 Center Street, New Bedford, MA**

Material application (general usage, i.e. adhesive, coating, potting, etc.): **Fiber Optic Epoxy**

J. O. Number/Project Name: **EOS/PM**

Request Infra-Red Spectra? ☐ YES ☒ NO

Originator Source/Code (other than Code 541): **562**

Indicate processing required by GSFC Materials personnel. Include the recipe, cure(s), and special instructions to be performed.

**None**

If material is to be tested in the "as received" condition, without further processing required, indicate in full the past history, recipe, cure(s), post cure(s), nomenclature of components, etc.

**Cured @ 120 degrees C for 10 minutes after automatic mixing and 3 minutes in centrifuge**

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\*\*\*\*\*

CVCN test specimen preparation and description: **cut up & put in boats**

Bar Position-CVCN Test Number	<b>25607 (7)</b>	<b>25608 (9)</b>	<b>25609 (9)</b>
Initial mass, holder and specimen, gm	0.264538	0.250444	0.273846
Mass of holder, gm	0.035022	0.035010	0.034572
Initial specimen mass @ 50 %RH, gm	0.229516	0.215434	0.239274
Final mass, holder & specimen, gm	0.263006	0.249102	0.272339
Total mass loss, specimen, gm	0.001532	0.001342	0.001507
Percent TML, specimen	0.67%	0.62%	0.63%
Average value TML	*****	<b>0.64%</b>	*****
Mass after 50 %RH re-soak, 23 C, 24hr, gm	0.263812	0.249870	0.273074
Total mass, water vapor regain, gm	0.000806	0.000768	0.000735
Percent water vapor regain	0.35%	0.36%	0.31%
Average value WVR @ 50 %RH	*****	<b>0.34%</b>	*****
Initial mass, collector, gm	1.730079	1.735126	1.738126
Final mass, collector, gm	1.730096	1.735134	1.738126
Collected mass - CVCN, gm	0.000017	0.000008	0.000000
Percent CVCN	0.01%	0.00%	0.00%
Average Value CVCN	*****	<b>0.00%</b>	*****

Remarks: CVCN (unweighable) on separator plate to \_\_\_\_\_ mm diameter. CVCN appearance as follows: \_\_\_\_\_ is not detectable on collector plates.

☒ thin; \_\_\_\_\_ heavy; **smoke** color; \_\_\_\_\_ transparent; \_\_\_\_\_ colored liquid;

☒ opaque; ☐ matte; ☐ interference fringes; ☐ foggy; ☐ distorts eye reflection; ☐ smooth; ☒ smoky; ☐ splotchy; ☐ partially opaque;

☐ clear liquid; ☐ liquid runs in excess; Deposit covers **15** % of collector disc.

Specimen appearance after test:

**No Visible Change**

Test started 4/18/01  
Pascal

Test completed: 4/19/01

Period 24 Hrs.

Pressure  $5.6 \times 10^{-5}$

Specimen Temp. 124.3 °C

Collector Temp. 24.8 °C

Analyst Dewey Dove & Debbie Thomas

VCM REV 14      25 JAN 2001

## Table 7

# MICRO VCM TEST REQUEST AND DATA SHEET PER ASTM E-595-93

(Requestor please read, then furnish all information above asterisks.)

Requested by: **Matt Bettencourt**

Phone: **6-8311**

Date: **4/12/01**

Material Identification (product name, number, description, classification, etc.)

**Angstrom Bond 9112, Fiber Optic Epoxy**

Manufacturer of Material (Name, City and State Address): **Fiber Optic, Inc., 23 Center Street, New Bedford, MA**

Material application (general usage, i.e. adhesive, coating, potting, etc.): **Fiber Optic Epoxy**

J. O. Number/Project Name: **EOS/PM**

Request Infra-Red Spectra? ☐ YES ☒ NO

Originator Source/Code (other than Code 541): **562**

Indicate processing required by GSFC Materials personnel. Include the recipe, cure(s), and special instructions to be performed.

**None**

If material is to be tested in the "as received" condition, without further processing required, indicate in full the past history, recipe, cure(s), post cure(s), nomenclature of components, etc.

**Cured @ 90 degree C for 15 minutes after automatic mixing and 3 minutes in centrifuge**

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\*\*\*\*\*

CVCN test specimen preparation and description: **cut up & placed in boats**

Bar Position-CVCN Test Number	25610 (10)	25611 (11)	25612 (12)
Initial mass, holder and specimen, gm	0.233235	0.239087	0.257544
Mass of holder, gm	0.033617	0.032973	0.033130
Initial specimen mass @ 50 %RH, gm	0.199618	0.206114	0.224414
Final mass, holder & specimen, gm	0.224238	0.230013	0.248400
Total mass loss, specimen, gm	0.008997	0.009074	0.009144
Percent TML, specimen	4.51%	4.40%	4.07%
Average value TML	*****	<b>4.33%</b>	*****
Mass after 50 %RH re-soak, 23 C, 24hr, gm	0.225476	0.231431	0.249450
Total mass, water vapor regain, gm	0.001238	0.001418	0.001050
Percent water vapor regain	0.62%	0.69%	0.47%
Average value WVR @ 50 %RH	*****	<b>0.59%</b>	*****
Initial mass, collector, gm	1.746686	1.746588	1.739651
Final mass, collector, gm	1.749516	1.749360	1.742468
Collected mass - CVCN, gm	0.002830	0.002772	0.002817
Percent CVCN	1.42%	1.34%	1.26%
Average Value CVCN	*****	<b>1.34%</b>	*****

Remarks: CVCN (unweighable) on separator plate to \_\_\_\_\_ mm diameter. CVCN appearance as follows: \_\_\_\_\_ is not detectable on collector plates.

\_\_\_\_\_ thin; \_\_\_\_\_ heavy; **blue** color; ☒ transparent; \_\_\_\_\_ colored liquid;

☐ opaque; ☐ matte; ☐ interference fringes; ☐ foggy; ☒ distorts eye reflection; ☐ smooth; ☐ smoky; ☒ splotchy; ☐ partially opaque;

☐ clear liquid; ☐ liquid runs in excess; Deposit covers **100** % of collector disc.

Specimen appearance after test:

**gummy**

Test started 4/18/01  
Pascal

Test completed: 4/19/01

Period 24 Hrs.

Pressure  $5.6 \times 10^{-5}$

Specimen Temp. 124.3 °C

Collector Temp. 24.8 °C

Analyst Dewey Dove & Debbie Thomas

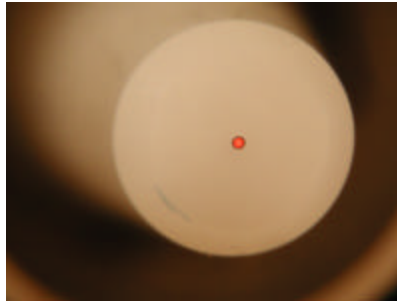
VCM REV 14      25 JAN 2001

## Table 8



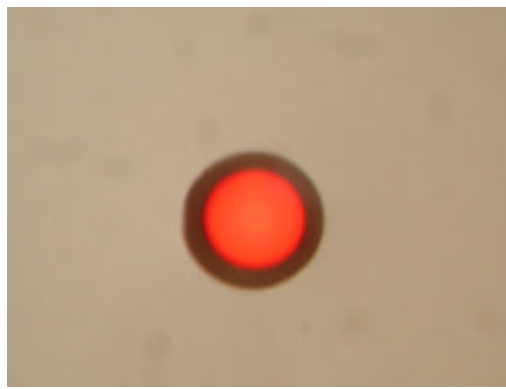
## Discussion

The fiber optic cables met the necessary space flight termination specifications. After termination each prepared cable was inspected visually, mechanically and optically. If any flaws were present the cables were re-terminated. None of the cables failed initial inspections (Illustration 4). The cables were polished properly and met all criteria for space flight termination.



**Illustration 4**

The fiber optic cables were required to have adequate performance levels before and after the outgas testing. Before and after the outgas testing the test cables were tested for their insertion loss. This testing showed the amount of light, or information, that was lost within the cable. The standard accepted value for insertion loss is 1 dB. All of the test cables had insertion loss values below this value prior to outgas testing (Table 2). However, after outgas testing, two of the cables did not have values for insertion loss within the accepted range (Table 8). The 9112 Cable # 1 and the AB9119 Cable # 2 had no light visible for the insertion loss reading. The light loss of these cables showed that some type of damage had occurred during the outgas testing of each of these cables. After failure analysis, it was learned that the short length of the test cables did not allow for the adequate amount of flex needed to prevent the fiber from breaking during the thermal expansion and contraction of the outer jacket. The post visual inspection showed no voids present around the ferrule and the fiber core on any of the cables (Illustration 5 ), but no light passed through 9112 cable #1 and AB9119 cable #2 so they failed final visual inspection and optical performance testing.



**Illustration 5**

The data for each epoxy during outgas testing are required to be compared to the standard values for space flight hardware. The standards for outgassing of materials during outgas testing are a TML of less than 1 percent and a CVCM of less than 0.10 percent. In the outgas testing of the epoxy in cable configuration each cable had a TML that was within the standards for outgassing (Table 4). However, when the two epoxies were tested alone in the E-595 testing apparatus the values showed different results (Table 4&5, 7&8). The AB9119, had a TML of 0.64 percent. This percentage is within the standards for outgassing of materials. The 9112, had a TML of 4.33 percent. This percentage was above the accepted value for TML. The values for CVCM were only taken during the testing of the epoxy alone. The AB9119 had a CVCM value of 0.00 percent. This value was well within the standards. The 9112, however, had a CVCM value of 1.34 percent. This value was significantly above the standards for the CVCM of outgas testing.

## Conclusions

The outgas testing of the fiber optic epoxy allowed for specific values to be documented that represent the epoxy's outgas characteristics. By ensuring that the fiber optic cables that were prepared for testing met the standards for space flight terminations and that each cable had an adequate performance level, the validity of the outgas characteristics was maintained. The values acquired during the outgas testing demonstrated that the AngstromBond 9119, epoxy had outgas characteristics that were within the acceptable ranges for flight qualified fiber optic epoxies. Yet, the values acquired for the, AngstromBond 9112, epoxy had characteristics that were not within the acceptable values. Both of the epoxies did not meet the requirements for space flight qualified epoxies thereby voiding the hypothesis that both epoxies would pass the outgas testing with acceptable characteristics. One epoxy passed, one did not.

The AngstromBond 9119 epoxy has the necessary outgassing characteristics to qualify for use in a space flight environment. The epoxy produced no adverse effects on the fiber optic cable's performance and did not shift due to the presence of a vacuum environment.

The AngstromBond AB9112 epoxy did not have the necessary outgassing characteristics needed to qualify for use in a space flight environment. While the epoxy did not have any adverse effects on the performance of the fiber optic cable or produce any shifts of the core while in the vacuum environment, the values for TML and CVCM obtained during the outgas testing were not within the needed standards that warrant qualification.

The testing of fiber optic epoxies in cable configurations should be performed with adequate length of fiber within the cabling to withstand the stresses caused by the expansion and contraction of the outer jacket. The results of the configuration testing were inconclusive although none of the optical fiber interfaces appeared to be affected by the outgassing of epoxy out of the ferrule when verified by visual inspection.

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